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Control of Strawberry Black Root Rot with Compost Socks

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Abstract

Black root rot (BRR) can severely limit productivity in perennial, matted-row strawberry systems. In annual production systems, fumigation temporarily controls soilborne diseases. This report describes for the first time a novel, raised-bed growing method that uses 100% mature compost as an alternative to fumigation. Compost is pneumatically blown into flexible mesh tubes ("compost socks") that lie directly on top of nonfumigated BRR-infested soil. Root health, plant growth, and yield of two cultivars, Chandler and Allstar, were evaluated after growth in compost socks, matted rows, and black plastic mulch at three locations in Maryland. Effects of a pre-plant soil drench with 20% vinegar were also examined. Results show that BRR symptoms were significantly reduced in all compost sock treatments, with or without vinegar, and that yields increased 16 to 32-times those observed in black plastic mulch or matted rows. In general, growth and yield of 'Chandler' surpassed that of 'Allstar' regardless of pre-plant vinegar and compost treatments. Vinegar alone was ineffective in preventing significant plant disease. Cotton-mesh compost socks readily decompose in soil eliminating the need for plastic removal. The compost sock system requires minimal equipment/supplies for startup, no fumigants, and is compatible with standard methods of weed management used in strawberry fields.

Introduction

Perennial (3- to 5-year), matted-row strawberry (*Fragaria* × *ananassa* Duchesne) systems are still used by many small acreage growers and "U-Pick" farms in regions with cold winters and warm summers, where plants produce an abundance of runners (4) that form the matted row. The latter offers small acreage strawberry producers conservative startup and maintenance costs and fewer management requirements than are required for annual "plasticulture" systems. Soil fumigation with methyl bromide (CH_3Br, MeBr) historically has been used to control soilborne plant diseases, pests, and weeds in both systems, but the ban on MeBr has prompted growers and researchers to evaluate various chemical, biological, and cultural alternatives (1,2,10,14). The plant disease suppressive activity of compost (8,12,14,16,18) and its value in soil quality improvement contribute to its beneficial potential in organic as well as conventional production systems.

Although many diseases are controlled by soil fumigation, black root rot (BRR) has been observed (author, *unpublished observations*) to aggressively reestablish within several months after initial treatment, particularly in older production fields (>10 years) in the mid-Atlantic region, where BRR can be the major factor limiting productivity. The disease involves a complex interaction between abiotic factors (temperature, soil type, and moisture), and one or more of several plant pathogens (4,9,11,16,17) that survive in soil, old crowns, and roots (*Rhizoctonia fragariae* Husan & McKeen, *Pythium* spp., *Cylindrocarpon* spp., *Fusarium* spp., and nematodes, particularly root lesion and root knot nematodes, *Pratylenchus penetrans* (Cobb) Filipjev & Schuurmans Stekhoven, and *Meloidogyne hapla* Chitwood, respectively. Plants that become infected with BRR produce few runners, weak branch crowns, and decreased yield. After the first harvest and onset of hot, dry weather, plant vigor declines precipitously and many plants die, even when pre-plant soil fumigants were used (author, *unpublished observations*).

Although strawberries can be grown outdoors hydroponically in North Florida (3,5,6,7,13), and in tunnels in the mid-Atlantic region (14,15), growers using matted-row systems are still interested in using their land in a sustainable, economical, but less input-intensive manner. While hydroponic bag or gutter systems under shelters clearly avoid weeds and soilborne diseases, they rely heavily on nonrenewable, expensive inputs to fill bags, purify recycling solutions, and dispose of spent plastics. In the studies reported here, common and renewable organic materials — compost and vinegar — were evaluated for rapid, low-cost field establishment of raised-row (hereafter referred to as compost socks) strawberries in nonfumigated soils with a history of BRR.

Compost and Vinegar Efficacy Trials

Field studies were conducted at three locations in central Maryland: Farm D (Davidsonville) with fine sandy loam soil; Farm G (Germantown) with silt loam soil; and Farm B (Beltsville) with loamy sand soil. All sites had prior histories of red stele, caused by *Phytophthora fragariae* Hickman, and BRR and had not been fumigated during the seven (Farm B) or two (Farms D and G) years prior to the study.

Vinegar drench and plastic mulch. Preliminary tests (author, *unpublished data*) with a single drench of 20% (v/v) acetic acid (a prospective organic herbicide) showed 100% destruction of *Rhizoctonia solani* and *Pythium spp.* in pots. Similar control of many annual weeds was achieved in several preliminary pot and field trials (J. Radhakrishnan, *unpublished data*) with one to several soil drenches and foliar sprays of the same concentration of acetic acid. These results along with the initial interest of organic growers in use of vinegar for weed control led us to include a soil drench with vinegar in this study. Fields were prepared using standard farm tillage equipment and practices in mid-August 2002 at Farms D and G, and early May 2004 at Farm B. In late August, designated subplots (5 m long × 5 m wide, with 0.6 m wide rows) at Farms D and G were treated with 20% (v/v) apple cider vinegar (Musselman's, Biglersville, PA) drench once prior to the placement of compost, transplants, or black plastic mulch (BPM). Vinegar was applied with manual pump-style sprayers at a rate equivalent to 1.2 liters per 1-m band of soil. No additional vinegar was applied for the remainder of the experiment and none was used at Farm B. After 7 days without rainfall or irrigation, compost and 1 mil, smooth, BPM (Robert Marvel Plastic Mulch, Annville, PA) was placed on the designated rows covering the previously vinegar-treated and -untreated areas. Interest in the use of vinegar drench as a possible alternative to traditional soil fumigants in combination with BPM and soilless propagated transplants led to the inclusion of this combined treatment as a comparison to the matted-row and compost sock systems. The BPM was stretched across the soil surface after drip irrigation tape was placed and operational; film edges were buried in soil. At Farm D, the BPM was laid on a slightly hilled bed, whereas at Farm G, it was applied on a raised bed.

Compost socks and transplants. Mature, leaf-yard-trimmings compost (Leafgro, Millersville, MD) was used to fill 20-cm-diameter compost socks (Filtrexx Inc., Grafton, OH) at Farms D and G using a pneumatic blower system attached to a flexible hose (Fig. 1). Leaf-grass-poultry (layer) manure compost produced at the USDA Composting Facility, Beltsville, MD and screened to < 0.32 cm was used to fill compost socks used at Farm B. Cotton-mesh socks were used at Farm D and polyethylene-mesh socks were used at Farms B and G. A drip irrigation system, 15 mil #515-12-450 T-tape (Berry Hill Irrigation,

Fig. 1. Farm G, August 2002. Filling of compost socks directly in the planting field with leaf-yard trimmings compost using flexible tubing from pneumatic blower truck located off-field (not shown).

Buffalo Junction, VA) with emitters spaced 30.5 cm apart and an emitter flow rate of 0.055 liter/min - linear m (4.5 gal/min-1000 linear ft) of row, was placed on bed centers (on top of compost socks, Fig. 2) and secured with metal landscape pins. Container-grown, soilless plug plants produced from gutter-propagated parent-plant runner tips (Davoncrest Nursery, Hurlock, MD) of cultivars Chandler and Allstar were transplanted 7 days after the vinegar drench in 2002 (Fig. 3). Plants were initially irrigated for 1 h immediately after transplanting and for 2 h each in the morning and afternoon on each of the following 7 days. They were subsequently fertigated with NH_3NO_3 (600 g N per acre/week) for 5 weeks in fall and spring. At Farm B, bareroot transplants (Indiana Berry, Huntingburg, IN) were transplanted on 12 May 2004 and irrigated/fertigated for 5 weeks in spring with 810 g N per acre/week in 2004 and 400 g N per acre/week in 2005. Plant and row spacing was 30.5 cm within-row (single) × 30.1 m long on 1.5-m centers. Wheat straw provided winter protection at Farms B and G, but not at Farm D (grower practice).

Fig. 2. Farm G, September 2002. Filled, polyethylene-mesh compost socks form continuous rows directly on top of unfumigated soil.

Fig. 3. Farm G, September 2002. Strawberry runner-tip plantlets transplanted into compost socks and irrigation drip tape secured on top.

Yield, plant, and root assessments. Fruit was harvested at each site during peak ripeness (late May-early June, see Table 1 for details), except at Farm D where intruders and excessive rain interfered with harvest. In early August 2003 at Farms D and G and September 2005 for Farm B, strawberry plant cover and root health were rated. Root health was rated according to a scale from 1 to 5, with 1 = mostly black, dark brown, no finely branched roots, and single crown; 2 = same as 1, except a 1 or 2 finely-branched roots present; 3 = half of all roots are black/dark brown and unbranched, and 1 or 2 crown branches; 4 = more white, fine, branched roots present than black/brown unbranched roots, and > 2 crown branches; and 5 = white, fine, and multi-branched roots and crown. Plant cover (1.3 m long × 0.5 m wide central portion of subplot rows) was rated according to a scale from 1 to 3, with 1 ≤ 25% of plot area covered with many weak plants and no daughter plants from runners; 2 = 25 to 50% plot area covered, few runners present; 3 = 50 to 74% plot area covered with more healthy vigorous plants than weak ones, at least half of the plants produced runners; and 4 ≥ 75% of the subplot covered with healthy vigorous plants all with rooted runners. Fungal isolations from roots were performed to identify causal agents. Roots were rinsed to remove adhering soil, disinfested 2 min in 1% (v/v) NaOCl, then rinsed three times in sterile deionized water and dissected aseptically into 5-mm segments before plating onto half-strength potato dextrose agar (PDA) with 100 ppm streptomycin sulfate to inhibit bacteria. Hyphal tips isolated from young colonies were subcultured on half-strength PDA before identification to genus using classical, morphological/taxonomic criteria.

Table 1. Root health and plant cover ratings and yield for Chandler (Chand) and Allstar in field tests with compost socks at three locations in Maryland.

Location	Treatment		Root health rating[w]		Plant cover rating[x]		Marketable yield[y] (g/ linear-m row+	
			Chand[z]	Allstar	Chand	Allstar	Chand	Allstar
Farm D	Matted row	vinegar	2.8c	2.2c	2.7bc	2.2c	110.3c	62.8c
		no vinegar	1.7c	1.4c	1.5c	1.7c	26.3c	10.7c
	Compost socks	vinegar	5.0a	4.1b	3.7a	3.4abc	406.3a	361.7b
		no vinegar	5.0a	3.7b	3.8a	3.7a	432.8a	320.7b
Farm G	Matted row	vinegar	2.0c	2.0c	2.0c	1.7c	148.6d	92.4d
		no vinegar	1.2d	1.2d	1.7c	1.2cd	67.1d	74.d
	Compost socks	vinegar	5.0a	4.2ab	3.8a	3.2a	425.7a	352.1ab
		no vinegar	4.7a	4.0 b	3.7a	3.3a	416.3a	325.8ab
	Black plastic mulch	vinegar	3.3bc	2.7bc	2.3bc	2.3bc	198.7c	216.5c
		no vinegar	1.7cd	2.3bc	1.8c	2.7bc	112.8d	203.2c
Farm B	Matted row		1.3c	4.0ab	1.8b	3.2ab	162.1c	333.7b
	Compost socks		0.7a	5.0a	3.1a	4.0a	363.8b	548.2a

[w] Rating Scale 1 to 5: 1 = mostly black, dark brown, no finely branched roots; 5 = white, fine and multi-branched roots (see text for details). Farms D and G were rated in August 2003; Farm B was rated in September 2005.

[x] Rating Scale: 1 ≤ 25% of plot area covered with many weak plants; 2 = 25-50% plot area covered; 3 = 50-74% plot area covered with more healthy vigorous plants than weak ones; 4 ≥ 75% of the subplot covered with healthy vigorous plants (see text for details). Rating period as in "a" above.

[y] Marketable yield was obtained from fruit that were red ripe or near red ripe, not injured, diseased, or deformed. Mean yields at Farm D were from three peak ripeness harvests (29 May, 2 and 5 June 2003); Farm G for five harvests (3, 6, 10, 13, and 17 June 2003); Farm B for seven harvests (23 and 26 May, 1, 9, 13, 16 and 20 June 2005).

[z] Values shown for all sites are means of three replications (n = 3). At each location, parameter means (root health, plant cover and yield) for all treatments and both cultivars followed by the same letter are not statistically different at $P \leq 0.05$ using the LSD test.

Data analysis. Analysis of variance of a split-split plot randomized complete block design with three replications was used to assess treatment effects at each location separately. Main plot effects were compost socks, matted-row, and BPM, whereas cultivar and vinegar drench were subplot effects. Differences among means were calculated with Fisher's least significant differences (LSD) test, with SAS Proc MIXED (version 9 for Windows, SAS Institute Inc., Cary, NC). Separate analysis by location was used because the 2003 harvest season was less than ideal. Low temperatures and heavy rains (BPM plots flooded) reduced yields at Farm D, and a heavy mid-season sap beetle, *Stelidota geminata* (Say), invasion at Farm G occurred after the rainy period. Soils, crop, and plant disease history at the three sites also were different, and compost/season in the Farm B trial differed from the other two farms.

The data show that, at all three sites, roots were more symptomatic of BRR and plant cover was reduced in soils without compost compared to those with compost sock treatments (Table 1). Overall, compost sock treatments produced significantly ($P < 0.05$) greater yields, healthier plant roots, and greater plant coverage in the rows than matted row or BPM, regardless of vinegar treatment or location (Figs. 4 and 5).

Fig. 4. Farm D, June 2003, cotton-mesh compost socks with strawberry runner-tip plug plants 9 months after planting. Bottom and sides of socks are decomposed, but root mass holds compost in position. Cover rating = 3 on a scale of 1 to 4, where 1 = < 25% of plot area covered with many weak plants; and 4 >75% of the subplot covered with healthy vigorous plants.

Fig. 5. Farm D, June 2003, soil-grown, matted-row, strawberry runner-tip plug plants 9 months after planting; cover rating = 1 on a scale of 1 to 4.

Symptomatic plants/roots were hard to find from most of the compost socks. Suppression of BRR in roots was observed visually at harvests and subsequently measured by examining roots and plating root sections after heat stress, 10 and 12 months after plots were established. A vinegar drench, while initially successful in controlling weeds prior to planting and throughout the fall/winter, did not inhibit common annual spring and summer weeds (*data not shown*) or root disease symptoms the year after planting.

Five fungal genera implicated in BRR (10,17) were consistently isolated from symptomatic strawberry roots of bioassay plants: *Pythium*, *Rhizoctonia*, *Fusarium*, *Cylindrocarpon*, and an unidentified sterile fungus. No attempt to identify the fungi to species was made because colony and microscopic morphology of isolates of the same genus were similar. No symptoms of red stele were found at any location, and no systematic attempt to quantify the frequencies of individual fungi was made. The high percentage of nonsymptomatic roots from compost sock plants was associated with rare recovery of any common BRR fungi from the healthy white roots that were sampled. In contrast, symptomatic roots (Table 1) were abundant and BRR fungi were readily recoverable in soil-grown plants, regardless of vinegar treatment, farm location, or use of BPM. No major incidence of leaf spot, mildew, or wilt was observed at any location. Fruit rot, substantial after rainy, hot/humid periods, affected all treatments uniformly.

Overall, a vinegar drench in these BRR-infested soils, although an initially promising strategy (preliminary data *not shown*), did not sustain plant protection against the BRR complex up through the harvest period and subsequent season, and there was no significant subplot or interaction effect. Vinegar treatment contributed to weed control primarily at the time of plot establishment, but this was not associated with significantly improved yields compared to the no-vinegar treatment (Table 1). The only significant difference obtained in yield with vinegar treatment was associated with its use in combination with the BPM at Farm G with 'Chandler' (Table 1). However, even BPM with the vinegar treatment did not result in yields as large as those from the compost socks at this location with both 'Chandler' and 'Allstar.' Unfortunately, BPM plots on the slightly hilled beds at Farm D were flooded so much during and shortly after heavy rains that plant stands were substantially compromised and reliable yield data were unobtainable.

These results indicate that compost socks have potential for use in nonchemical protection of perennial row strawberry plants against BRR in Maryland. Unlike plasticulture systems, soilless bag culture, and solarization procedures, weed management must still be incorporated into the crop management program of compost sock and matted-row systems. Differences in compost quality might influence results, but in these tests with two different composts and three locations, healthy roots completely permeated socks filled with either type of compost and did not grow out of the sides or bottom of the socks into the soil. Runners were able to establish on the tops and sides of socks despite the continued presence of the BRR fungal agents in the soil underlying and adjacent to the compost socks. Salts were not observed to be a problem, and irrigation water filtered down through the socks to the soil preventing salt accumulation in the sock.

Recent availability of soilless, container-grown plug plants as an alternative to soil-propagated bare-root transplants offer the prospect of limiting the inadvertent introduction of BRR into new plantings. The plug plants used on Farms D and G, with their smaller size and roots, were easier to transplant into the compost socks than were the traditional bare-root transplants used at Farm B. Pneumatic filling and direct placement of compost socks in the field from a remote truck eliminates additional compaction in the crop area from field equipment. Filling and placement of socks is rapid, e.g., ~ 300 m/h for 35% moisture compost and economical ~ $3000/acre (complete for compost, socks, and installation) when compared to fumigation, solarization, or soilless bags. All of the latter are single-season treatments and do not contribute to soil quality improvement in the long-term as does the addition of stabilized organic matter such as compost. They also require extensive use of non-biodegradable film that must be removed and disposed of appropriately on an annual basis. Compost socks achieve control over the root zone environment much as other soilless systems do, and they can remain for more than one season. In addition, compost has beneficial effects not only on chemical and physical properties of soil, but also on biological properties that directly or indirectly impact positively on plant growth promotion (12,18). By selecting biodegradable material, such as recycled cotton, in manufacturing the mesh sock, disposal costs at the end of the useful life of the beds can be avoided.

Summary

In conclusion, this series of field evaluations on unfumigated soils has shown compost socks significantly improved plant and root health, plant coverage of the row, and yields by limiting symptoms of BRR in plants throughout the entire first season unlike the matted-row and the BPM systems treatments. A vinegar drench prior to establishment of planting beds had a positive, short-term effect on weed-control, but ultimately did not significantly or consistently reduce BRR symptoms in treatments without compost socks. In general, 'Chandler' was more productive on compost socks than was 'Allstar,' but further studies are needed to determine the spectrum of cultivar responses to the compost sock system and multi-year effects.

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